Poisoning Characteristics of a Palladium-Based Trace Contaminant Control System Catalyst

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Removal of trace chemical contaminants (resulting from materials offgassing and human metabolic processes) from a spacecraft cabin atmosphere is necessary to provide crew members with an acceptable environment in which to live and work in space. Current spacecraft systems for controlling contaminants employ either adsorption, catalytic oxidation, or a combination of these technologies. In particular, the contamination control system designed for the *International Space Station* uses both adsorption by activated charcoal and high-temperature catalytic oxidation using a commercially available palladium catalyst. Charcoal is used to remove volatile organic compounds, while the catalytic process targets hydrocarbons that are poorly removed by the charcoal. As the activated charcoal adsorption capacity is consumed, trace contaminants such as chlorocarbons, chlorofluorocarbons, and sulfides which can adversely affect the catalytic oxidation of hydrocarbons can enter the catalytic reactor. A thorough understanding of the effects of these compounds on catalytic oxidation of hydrocarbons is necessary to adequately maintain the contamination control systems used onboard spacecraft.

The major objective of the project is to study the effects of catalytic poisons on the ability of a palladium-based catalyst to oxidize hydrocarbons effectively. Also, the reversibility in these effects is being investigated to help determine onboard maintenance requirements for the system. Of particular interest to the investigation are the effects of dichloromethane, hydrogen sulfide, 1,1,2-trichloro-1,2,2-trifluoroethane, and bromotrifluoromethane on the catalytic oxidation activity for methane. Such chemicals are frequently observed in spacecraft cabin atmospheres and include compounds considered as keys in the design of spacecraft contamination control systems. Methane was chosen as the reference hydrocarbon because it is difficult to oxidize. Also, the palladium catalyst performance for methane oxidation has demonstrated a high degree of sensitivity to the selected poisoning compounds. Understanding the effects of varying poison concentration is central to the investigation.

The catalyst, a one-eighth-inch cylindrical alumina pellet supporting a 0.5-percent palladium catalyst, is placed in an automated test rig and heated to 400 °C. At that temperature, methane oxidation is nearly 100 percent. The fresh catalyst is operated in the absence of poisons until thermal stability is achieved—a process that takes approximately 3 days. Baseline tests are then performed for each poisoning compound at different concentrations. During the baseline runs, thermal ramps between ambient and normal operating temperatures are conducted to determine the effects of the poison on the methane reaction rate. The products of the poisoning compound’s oxidation are also determined at this time. After the baseline runs are completed, a cyclic poisoning study is conducted in which catalyst poisons are injected into the test rig to produce a poisoning effect; the injection is then stopped to allow the catalytic activity to recover.

Results have shown that the catalyst is irreversibly poisoned by sulfide compounds; concentration of the sulfide compound entering the catalytic reactor only affects the rate at which poisoning occurs. Fortunately, since sulfide production onboard a spacecraft is a very small component of human metabolism, the adsorption processes used before the catalytic reactor can protect it from harm. Chlorocarbon poisoning has been shown to be repeatedly reversible to the same activity level after more than the equivalent of 2 years of cyclic exposure. Although complete recovery of methane oxidation activity is not achieved, the single-pass efficiency recovers to between 85 and 90 percent after each exposure to dichloromethane. This result is important in determining the useful life of both the charcoal and catalyst beds.

Project findings indicate that the sulfide breakthrough of the charcoal bed is the most critical element to be considered for scheduling system maintenance activities. Future work on the effects of chlorofluorocarbons on methane oxidation performance are planned. The effects of fluorine on catalytic activity are unknown, as is their degree of reversibility.

The results of the research are helping to design and operate trace contaminant control systems used onboard spacecraft more effectively and may be useful in designing commercial emissions control systems.

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